

Chapter 6

Optical Fibre Testing

Optical test equipment are devices used to check light propagation, losses, and splice through the fibre. If there is a fault in the device they locate the fault and help in rectifying them. Once the fault position is located it is rectified.

An ideal test equipment should have the following features—

- Test equipment should be very compact.
- It should be lightweight and portable.
- The results provided by the equipment should be very accurate.
- The equipment should be able to sustain extreme environmental conditions like temperature, humidity, etc.
- The equipment should be connected to the fibre in a very simple way.

Testing is utilised to assess the execution of fibre optic components, cable plants and frameworks. As the components like fibre, connectors, splices, LED or laser sources, locators and receivers are being produced, testing affirms their execution determinations and sees how they will cooperate. Creators of fibre optic

cable plants and systems rely upon these particulars to decide whether systems will work for the arranged applications.

Testing fibre optics requires special tools and instruments which must be proper for the components or cable plants being tested.

Standard test procedures

Most test procedures for fibre optic component specifications have been standardised by national and international standard bodies. Several organisations have become involved in standardisation issues relating to optical fibre measurements. The International Telecommunication Union (ITU) recommended several standards for fibre transmission systems and fibre measurements. These are known as Fibre Optical Test Procedures (FOTPs) and optical fibre system test procedures (OFSTPs). These standards are published by the Electronics Industries Alliance (EIA) and telecommunication industries. In order to perform these tests, the basic fibre optic instruments are the power meter and OTDR. Hence, there are generally two types of test equipment generally used.

1. Power meter
2. Optical time domain reflectometer (OTDR)

These and some other specialised instruments are described below.



Fig. 6.1: Optical Time Domain Reflectometer

Optical time domain reflectometer

Optical Time Domain Reflectometer (OTDRs) as shown in Fig. 6.1 are useful tools for locating fibre faults. OTDR is typically used for long range (upto several kilometres) measurements. The OTDR is a device that launches a pulse of light into one end of an optical fibre and records the amount of light energy that is reflected back. The high resolution OTDR allows the fibre optic technician to see what is happening in the fibre optic link or cable undergoing the test. With the OTDR, the fibre optic link or cable is no longer a black box. The fibre optic technician can see how light passes through every segment of



the fibre optic link. Light reflecting back in an optical fibre is the result of reflection or backscatter. Light is scattered along the length of the optical fibre. The light that travels back toward the OTDR, is considered as backscatter. The OTDR is typically a battery-powered device, which is quite useful when no electrical power is not available. Always keep the spare battery charged, while performing test. Light being reflected back from the fibre is actually of two types. The first type is a constant low-level reflection that is created by the fibre. This is called “Rayleigh backscattering”. Rayleigh backscattering originates from the natural reflection and absorption of contaminations inside optical fibre. Whenever hit, a few particles of glass divert the light in various ways, creating both signal attenuation and backscattering.

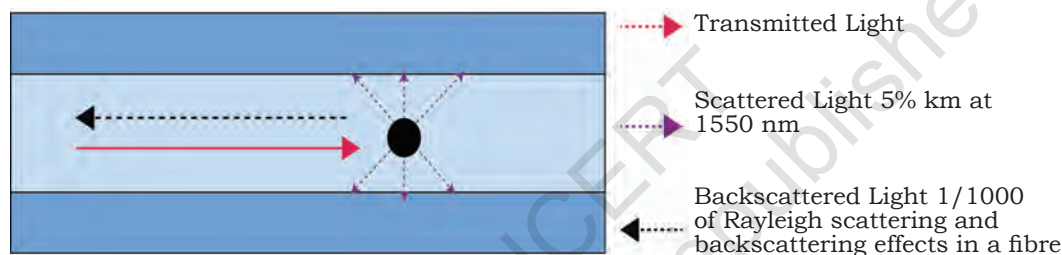


Fig. 6.2: Rayleigh scattering and backscattering in optical fibre

The second type of reflection is called “Fresnel reflection”. At the point when the light hits a sudden change in refractive index, for instance, from glass to air at a fibre connector interface, a higher measure of light is reflected back, which can be thousands of times greater than the Rayleigh backscattering. Fresnel reflection can be viewed as spikes in an OTDR trace as shown in the Fig. 6.3. Examples of such reflections are those created due to connectors, mechanical splices, bulkheads, fibre breaks or opened connectors.

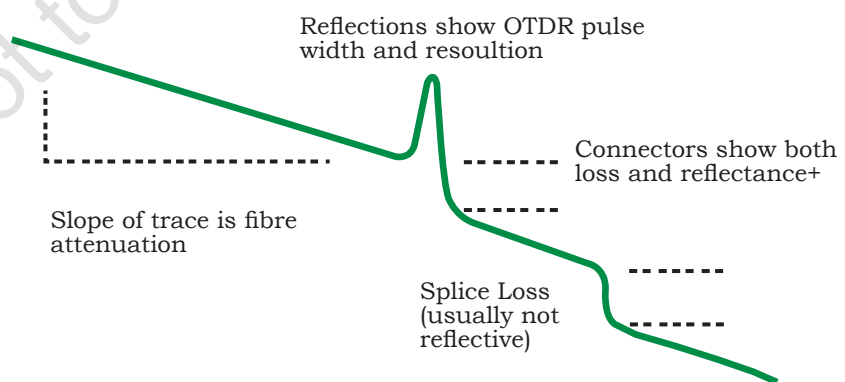


Fig. 6.3: Trace of signal in OTDR

NOTES

OTDR measures optical distance between—

- elements (splices, connectors, splitters, multiplexers)
- faults
- end of Fibre

OTDR also measures—

- loss of splices and connectors
- ORL (optical return loss) of link or section
- reflectance of connectors
- total Fibre attenuation

The use of OTDR is usually defined by a two-step process—

1. Acquisition: OTDR takes the input data and displays the results either numerically or graphically.
2. Measurement: Technicians analyse the data and based on the result print, or store the data or work with the next fibre acquisition.

Acquisition

OTDRs automatically select the acquisition parameters for a particular fibre by sending out test pulses in a process known as auto-configuration. Using the auto-configuration feature, technicians select the wavelengths to test the acquisition (or averaging) time and the fibre parameters (for example refractive index). Two major approaches used when configuring an OTDR are—

1. technicians simply allow the OTDR to auto-configure and accept the acquisition parameters the OTDR selects.
2. more experienced technicians allow the OTDR to auto-configure then analyse the results briefly and change one or more acquisition parameters to optimise the configuration for the particular test requirements.

Measurement

Most modern OTDRs perform fully automatic measurements with very little input from technicians. In general, there are two types of events which occur—reflective and non-reflective.



Reflective Events: These events occur where there is discontinuity in the fibre causing an abrupt change in the refractive index. It can occur at breaks, connector junctions, mechanical splices, or the indeterminate end of the fibre. For reflective events, mechanical splices undergo loss which typically ranges from 0.1 to 0.2 dB (Fig. 6.4).

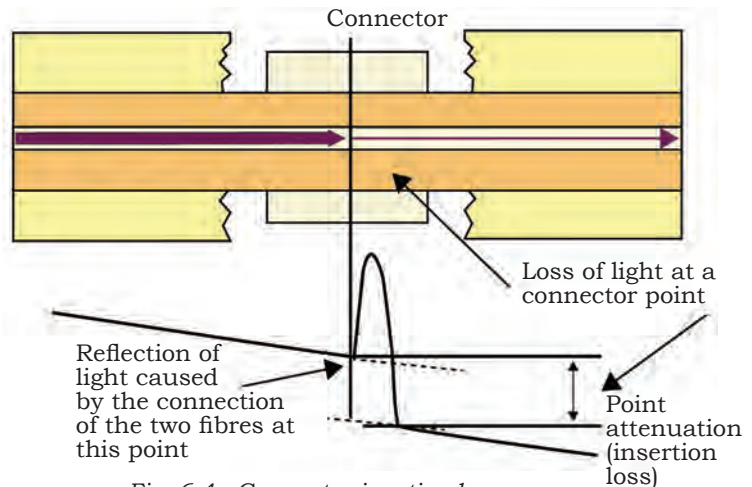


Fig. 6.4: Connector junction loss

If two reflective events occur very close together, the OTDR may have problems measuring the loss of each event. In this case, it displays the loss of the combined events, which typically occurs when measuring a short fibre length (Fig. 6.5).

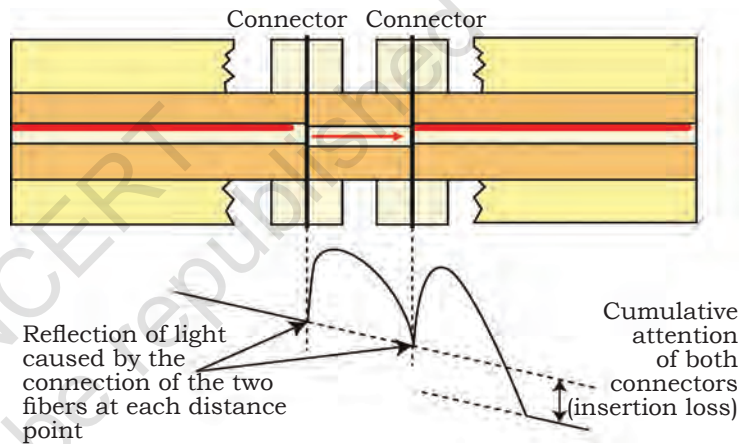


Fig. 6.5: Reflective index when junctions are located close to each other

Non-reflective Events: These events occur where discontinuities are absent in the fibre and are generally produced by fusion splices or bending losses, such as macro bends. Typical loss values range from 0.02 to 0.1 dB, depending on the splicing equipment and operator (Fig. 6.6).

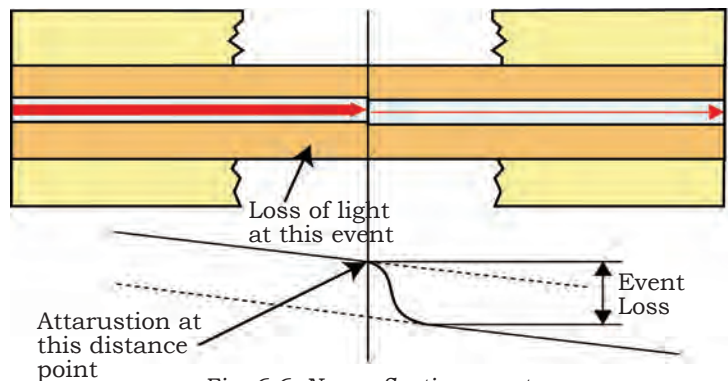


Fig. 6.6: Non-reflective events

Elements of OTDR

The basic elements of an OTDR are shown in Fig. 6.7.

- The light source (LASER) which produces focussed beam of light is used to generate light pulse.

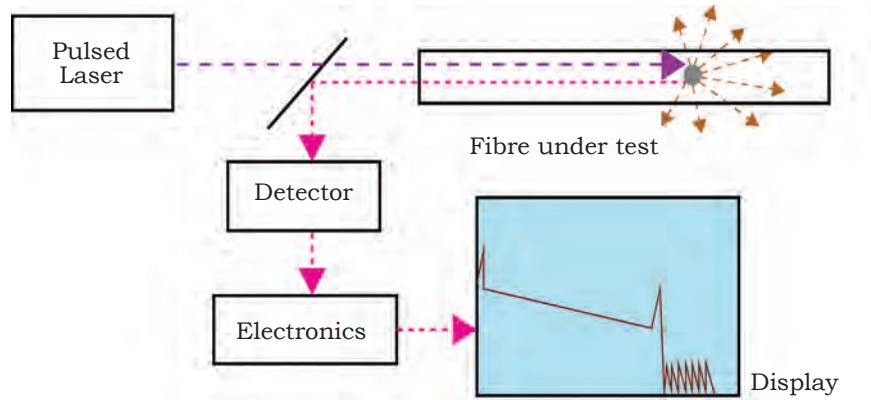


Fig. 6.7: Elements of OTDR

- This light pulse is coupled into the optical fibre which is used for the testing.
- At the point when the light is reflected from the fibre, it is passed through the detector. This detector changes the light signal into electrical signal, which is then enhanced and recorded in the display of OTDR.

In the market three types of OTDRs are generally available. For example, laboratory OTDRs are generally used in test labs. They have an extremely wide range with many options.

Mini OTDRs: These OTDRs are portable and designed for field testing. They have built-in screens to see the data. They also provide data storage as traces which are collected in the field.

PC-based OTDRs: As the name suggests, OTDRs can be connected to personal computers. These computers can work with Windows operating systems. They allow saving traces produced by the fibre on a disk on the computer, and then transfer saved data between computers.

OTDR test set-up: OTDRs are generally used for testing the signal with a launch cable and hence use a receiver cable. It allows the launch cable to settle down after the test pulse is sent into the fibre to determine its loss. It provides a reference connector for the first connector on the cable under test. On the far end, a receiver cable may be used to allow measurements of the connector on the end of the cable under test.

Practical Activity : To study trace of OTDR

Material required

- OTDR

Steps to follow

The OTDR displays time or distance on the horizontal axis and amplitude on the vertical axis, as shown in Fig. 6.8.

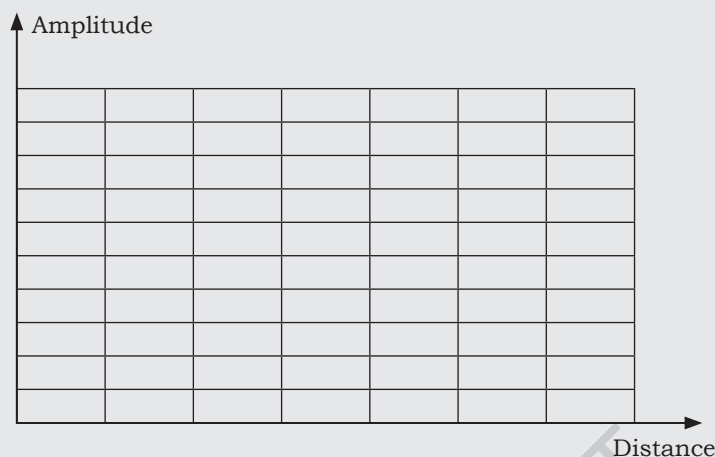


Fig. 6.8: OTDR displays

Step 1: The horizontal axis can typically be programmed to display distance in feet, meters, or kilometres.

The vertical axis is not programmable. The vertical axis displays relative power in dB.

Step 2: OTDR creates a trace like the one shown in Fig. 6.9. The trace shows event loss, event reflectance, and optical fibre attenuation rate. The OTDR can horizontally and vertically zoom in on any section of the trace. This permits a more detailed inspection of the optical fibre or event.

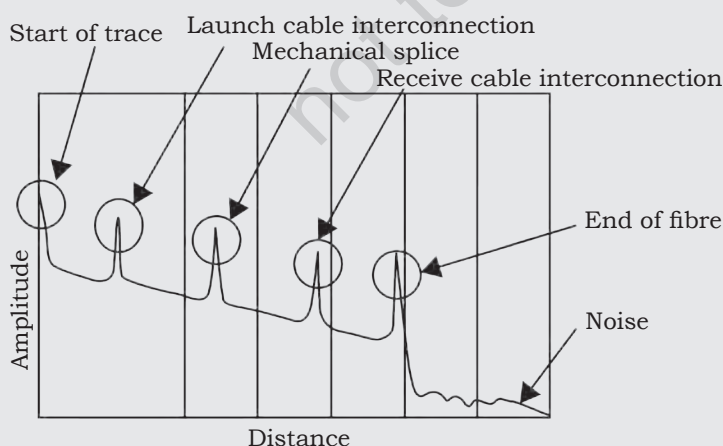


Fig. 6.9: Study of the trace of OTDR

Step 3: The slope of the fibre trace shows the attenuation coefficient of the fibre and is calibrated in dB/km.

NOTES

Step 4: Select the type of mode (single mode or multimode) and wavelength in nanometer (nm) in which you want to test the performance (eg., 1310 nm or 1550 nm) using the tab buttons.

Step 5: You can also select length of the system and power of the signal to be measured on the system. You can also select acquisition time.

Step 6: Clean your connector before connecting to the fibre cable of the test box.

Step 7: Click on the start button of OTDR.

Step 8: It shows the performance of the fibre upto 300 meters.

Step 9: The first spike shows that neither reflection nor attenuation is due to the first connector and is regarded as dead zone.

Step 10: The rest of the spike shows the reflections through connector. If one fibre is connected to another fibre by splicing then OTDR shows a spike value in dB.

OTDR specification

OTDR (Optical Time Domain Reflectometer) is a fibre test instrument for technicians or installers to characterise an optical fibre. The OTDR needs to be setup correctly prior to testing, to provide accurate readings. When setting up the OTDR, you need to select the correct fibre type, wavelength, dynamic-range and pulse width. This process takes only a couple of minutes and ensures the most accurate results possible. It is important to understand the specifications which may affect the performance of the OTDR which can help users get maximum performance from their OTDRs.

Fibre type

Each light source or light source module in an OTDR is designed for one or several specific optical fibre types. A multimode module should not be used to test a single-mode optical fibre, and vice versa. Before heading for the test site, ensure that your OTDR has the correct module for the optical fibre to be tested.

Wavelength

The wavelength that your OTDR can test depends on the light source module or modules in your OTDR. Some



light source modules contain a single laser while others contain two different wavelength lasers. A light source with two lasers allows testing of the optical fibre at two wave-lengths without disconnecting the cable under test. This simplifies testing and reduces testing time.

Dynamic range

The dynamic range is an important characteristic since it determines how far the OTDR can measure. It is specified by OTDR vendors is achieved at the longest pulse width and is expressed in decibels (dB). The distance range or display range sometimes specified is usually misleading as this represents the maximum distance the OTDR can display, not what it can measure.

Dead zone

The OTDR dead zone refers to the distance (or time) where the OTDR cannot detect or precisely localise any event on the fibre link.

When a strong reflection occurs, the power received by the photo diode can be more than 4,000 times higher than the backscattered power. This causes detector inside the OTDR to become saturated with reflected light. Thus, it needs time to recover from its saturated condition. During the recovering time, it cannot detect the backscattered signal accurately which results in corresponding dead zone on OTDR trace. This is like when your eyes need to recover from looking at the bright sun or the flash of a camera. In general, higher the reflectance, longer the dead zone is. Additionally, dead zone is also influenced by the pulse width.

Pulse width

Pulse width determines the size of the dead zone and the maximum length optical fibre that can be tested. A short pulse width produces a small dead zone. However, a short pulse width

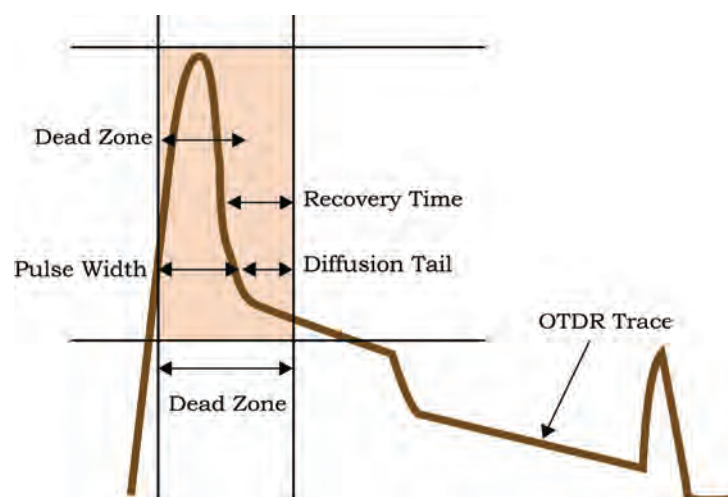


Fig. 6.10: Dead zone and pulse width

reduces the length of optical fibre that can be tested. The pulse width should be selected so that the trace never disappears into the noise floor.

If the pulse width is set properly, the trace will stay smooth until the end of the fibre optic link. If the pulse is set too wide, events may be lost in the dead zone.



Fig. 6.11: Power meter

Fibre optic power meters

Power in a fibre optic system is like voltage in an electrical circuit. The term usually refers to a device for testing power of optical signal in fibre optic systems. Measuring power requires only a power meter as shown in Fig. 6.11. It's important to have enough power, but not too much. Level of power should not be very less otherwise the receiver may not be able to distinguish the signal from the noise. Also, too much power overloads the receiver. Power meters are calibrated in dBm and the proper wavelengths matching the source should be used. The measured optical power and set wavelength is displayed on the display unit.

When combined with a light source, the instrument is usually called an Optical Loss Test Set (OLTS). A number of portable, battery operated power meter are commercially available. Some of these instruments are of small dimension and therefore designed to be handheld, while other which provide greater accuracy and stability are larger in size. Such devices usually measure power in dBm.



Fig. 6.12: Light source

Light source

A light source is a device that provides source of energy for attenuation measurements. It includes a source, either an LED or a laser. LEDs are typically used for multimode fibre. On the other hand, lasers are used for single mode fibre applications.

Insertion loss tests

In order to know how effectively your fibre optic cables are transmitting, you'll need to test each one for optical



loss. The term 'optical loss' also called insertion loss, describes the difference between the amount of light sent into the transmitting end of a fibre optic cable, and the amount of light that successfully makes it to the cable's receiving end. Hence, in order to certify optical fibre cable you must measure optical loss using an optical power meter and proper optical light.

Practical Activity: To test insertion loss in optical fibre

Material required: Power meter device, test cable, light meter

Steps to be followed

Step 1: Connect the optical light source to the transmitting end of the test cable as shown in Fig. 6.13.

Step 2: Connect the power meter to the receiving end of the test cable.

Step 3: Turn on the light source and select the wavelength you want for the loss test.

Step 4: Turn on the meter, select the "dBm" or "dB" range and select the wavelength you want for the loss test.

Step 5: Measure the power loss at the meter. Record the optical power displayed on the optical power meter. This number is the reference power measurement in dBm. This number is typically around (-)20 dBm with a 62.5/125 µm multimode optical fibre and (-)23 dBm with a 50/125 µm multimode optical fibre.

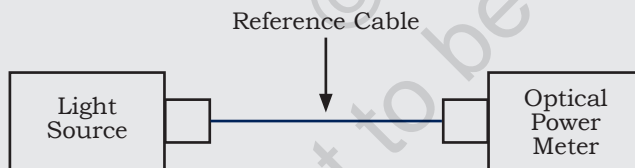


Fig. 6.13: Connection with power meter

Note: A typical OPM measures accurately under most conditions from about 0 dBm (1 milliwatt) to about -50 dBm (10 nanowatt), although the display range may be larger. Above 0 dBm is considered 'high power', and specially adapted units may measure up to nearly +30 dBm (1 watt). Below -50 dBm is 'low power', and specially adapted units may measure as low as -110 dBm.

To calculate dBm from power meter output:

The linear to dBm calculation method is:

$$\text{dBm} = 10 \log (P1/P2)$$

where P1 = measured power level (e.g., in milliwatt)

P2 = reference power level, which is 1 milliwatt

Remember: Typically, OPM can be operated in the wavelength of 850 nm, 1300 nm, 1490 nm, and 1550 nm. Power meter is

NOTES

calibrated from the range of 850 nm to 1650 nm. The way you operate calculator in the same way using keys or tabs set the required wavelength.

Terms to Understand

Patch Cord

An optical fibre patch cord is a two-fibre cable. It uses the same connector type and optical fibre type as the optical fibre cabling that it is connected to. The optical fibre patch cord is used at cross-connections to connect optical fibre links. They are also used to connect telecommunications equipment. The patch cord must meet the cable transmission performance requirements and physical cable specifications. Position A goes to position B on each optical fibre. The connector that plugs into the receiver is position A and the connector that plugs into the transmitter is position B.

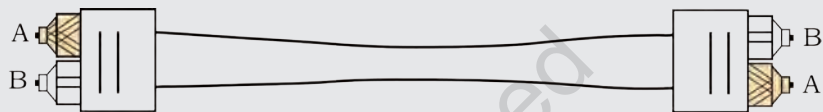


Fig. 6.14: Optical fibre patch cord terminal configuration

Test Jumper

The terms 'patch cord' and 'jumper' are often interchanged. A patch cord is a two-fibre cable. However, the term 'patch cord' is often used to describe a single-fibre cable. IEEE standard 802.3 defines a jumper used for bidirectional transmission and reception of information. A test jumper can be a single-fibre cable or a multi-fibre cable. In the fibre optic industry, the test jumper has several names. The test jumper connected to the light source is typically called the transmit jumper. The test jumper connected to the optical power meter is typically called the receiver jumper. Test jumpers must have a core diameter and numerical aperture nominally equal to the optical fibre being tested. A jumper shall be no less than one meter in length and no greater than 5 meters in length. Test jumpers should be cleaned and inspected prior to making measurements. The end face of each connector should be evaluated under a microscope. This means that there can be no scratches, notches, or chips in the end face of the optical fibre.

Check Your Progress

A. Multiple Choice Questions

1. Test equipment means devices meant for _____.
 - (a) testing a device
 - (b) measuring a device
 - (c) testing fibre
 - (d) measuring fibre



2. Optical test equipment are the devices used to check _____.
 - (a) light propagation
 - (b) losses
 - (c) splice
 - (d) reflection
3. Optical power can be measured by using _____.
 - (a) power meter
 - (b) OTDR
 - (c) test fibre box
 - (d) optical Coupler
4. There are three types of OTDR generally used. They are _____.
 - (a) mini OTDRs
 - (b) PC-based OTDRs
 - (c) OTDR test set up
 - (d) None of the above
5. An OTDR screen has X axis and Y axis. Which one of the following is true?
 - (a) The X axis measures distance and Y axis measures attenuation.
 - (b) The X axis measures attenuation and Y axis measures distance
 - (c) The X axis measures time and Y axis measures attenuation
 - (d) The X axis measures distance and Y axis measures time
6. OPM can be operated in the wavelength of _____.
 - (a) 850 nm
 - (b) 1300 nm
 - (c) 1490 nm
 - (d) 1550 nm
7. The slope of the fibre trace shows _____.
 - (a) the attenuation coefficient of the fibre and is calibrated in db/km.
 - (b) the attenuation of the fibre and is calibrated in db/km.
 - (c) the attenuation coefficient of the fibre and is calibrated in db.
 - (d) the reflection coefficient of the fibre and is calibrated in db/km.
8. LASER produces _____.
 - (a) focussed beam of light
 - (b) unfocussed beam of light
 - (c) focussed beam of rays



NOTES

9. Fresnel reflections cause a vital OTDR specification referred to as _____.
 - (a) dead zones
 - (b) live zone
 - (c) test zone
 - (d) None of the above

B. State whether True or False

1. Mini OTDRs are not portable and designed for field testing.
2. PC-based OTDRs can be connected to the personal computer.
3. OTDR test set up are generally used for testing the signal with a launch cable and hence use a receive cable.
4. Power meter consists of two ports. One port can be joined to reflectometer to measure power and other slot is connected to light source.
5. The slope of the fibre trace shows the attenuation coefficient of the fibre and is calibrated in dB.
6. OCWR stands for Optical Continuous Wave Reflectometer.
7. Rayleigh backscattering originates from the natural reflection and absorption of contaminations inside optical fibre.
8. Rayleigh backscattering causes a vital OTDRs specification referred to as dead zones.
9. OTDR equipment is not able to sustain extreme environmental conditions like temperature, humidity, etc.
10. A typical optical power meter consists of a measuring amplifier, calibrated sensor, and display.

C. Answer in Brief

1. What do you mean by test equipment?
2. What is OTDR?
3. What is power meter?
4. What do you mean by dead zone?
5. What does OTDR test?
6. When do I need to use a launch cord (cable) with my OTDR?
7. Difference between OTDR and power meter.
8. Draw and explain block diagram of OTDR.
9. What does OTDR measure?
10. How faults in cable are detected?
11. What is backscattering?
12. Which solution is used to clean the connector?
13. Name the types of OTDR available in the market?

